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1 Method for Assessing the Integrity of a Structure

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3 The present invention relates to a method for
4 assessing the integrity of a structure. The method
5 according to the present invention involves the
6 measurement of the dimensions of the structure and
7 the loading and thereafter analysing the results of
8 those measurements in order to calculate a value for
9 the integrity of the structure.

10

11 In the process industry, one of the biggest sources
12 of failures and shutdown for process plants is in
13 pressurised piping and vessel systems. In the prior
14 art, systems are known which monitor and assess
15 plants in order to be able to predict a failure.
16 According to the prior art, the wall thickness of
17 structures, such as piping, is simply monitored in
18 order to perform simple calculations and to predict
19 a trend, for instance in the wear and/or the
20 corrosion of such a structure. Alternatively,
21 machinery-based corrosion and vibration monitoring
22 systems are used. These systems are grossly

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1 inaccurate as over 85% of failures occur at non-
2 straight pipe areas, due to structural loadings,
3 corrosion/erosion, fatigue, pulsation or vibration
4 ("Hydrocarbon" magazine). The monitoring and
5 assessment technologies according to the prior art
6 are based on "risk analysis". These systems use
7 probability to estimate failure, and in doing so
8 predict suitable inspection intervals. An important
9 disadvantage of such an approach is that these
10 systems do not use real-time measurements in order
11 to calculate real-time load and load changing
12 mechanisms.

13

14 A system for monitoring a pipe segment for instance
15 is known from the European Patent Application EP
16 0358994. The method according to EP 0358994 is
17 adapted to measure a corrosion/erosion trend. The
18 system is confined to the change in the main pipe
19 wall thickness to predict the future thickness of
20 the pipe wall. According to this document the
21 emphasis is on measuring the corrosion/erosion rate
22 and using statistical techniques to predict future
23 rates and trends. The estimated stress in a pipe
24 wall is calculated using the following equation:

25

26 Stress = pressure x radius x estimated factor
27 thickness

28

29 This equation only calculates pressure loading in
30 straight pipes. No other loadings are considered.
31 As the thickness decreases there is a danger of
32 pipewall rupture. Therefore the information is used

1 in order to predict the maximum time interval before
2 the next inspection of the pipe welds. The
3 information collected according to EP0358994, in
4 practice, is not very helpful, as very few plant
5 failures are caused by main pipewall rupture. This
6 means that the information collected by means of
7 EP0358994 has only limited value.

8

9 Additionally, according to the prior art it is known
10 to use acoustic pulsation, vibration and condition
11 monitoring in order to monitor and assess the
12 integrity of a structure. The disadvantage of those
13 techniques is the fact that those techniques are
14 both specialist tasks and extremely expensive.
15 Because of the high costs involved with those
16 techniques normally these techniques are only
17 undertaken if failure is expected or has occurred.

18

19 In view of the disadvantages and limitations of the
20 methods for assessing the integrity of a structure
21 according to the prior art, it is an object of the
22 present invention to provide a method according to
23 the introduction wherein load-changing mechanisms
24 and dimension changing mechanisms, as they occur,
25 are taken into account in the calculations of the
26 integrity of the structure.

27

28 To obtain these objects, the method according to the
29 present invention comprises the steps of:

30

31 i) collecting data relating to the initial
32 dimensions of the structure,

- 1 ii) creating a computer model of the structure,
- 2 iii) collecting load data relating to the estimated
- 3 load on the structure,
- 4 iv) analysing the structure, using the computer
- 5 model of the structure and the load data, in
- 6 order to define areas which are subject to
- 7 relatively high stresses,
- 8 v) measuring, after a time interval, the
- 9 dimensions of the structure in high stress
- 10 areas,
- 11 vi) updating the computer model of the structure,
- 12 using the results of step v),
- 13 vii) re-analysing the structure, using the updated
- 14 computer model and the load data, in order to
- 15 calculate a value for the integrity of the
- 16 structure.

17

18 In the present description the wording "computer
19 model" is used. The wording "computer model" refers
20 to a data set representing a structure, which data
21 set can be analysed by means of an appropriate
22 finite element analysis technology. By means of
23 this finite element analysis technology the strains
24 and stresses occurring in the structure can be
25 calculated.

26

27 In the present description reference is made to "a
28 value for the integrity of the structure". The
29 wording "value for the integrity of a structure"
30 refers to whether a structure is "fit for service"
31 or not. When the value for the integrity of a
32 structure is calculated, it is assessed whether the

1 structure is fit to perform its normal tasks. That
2 means that the value for the integrity of a
3 structure can refer to a minimum wall thickness, a
4 maximum stress in the material of the wall, a
5 maximum strain in the material of a wall, or similar
6 feature.

7
8 According to the present invention data relating to
9 the initial dimensions of a structure are collected.
10 These data are used to create a computer model of
11 the structure. That means that it is possible to
12 use a finite element method in order to calculate
13 strains and stresses in the structure. Thereafter
14 data is collected relating to the estimated load on
15 the structure. By means of the finite element
16 method the structure can then be analysed, using
17 both the computer model and the load data. The
18 result of this analysis is that individual areas can
19 be defined which are subject to relatively high
20 stresses. Because of the fact that the high stress
21 areas are identified, it is clear in which areas of
22 the structure future problems can be expected.

23
24 If the results of the analysis of the structure
25 reveal that the strains and stresses in the
26 structure are within safety limits, the structure
27 thereafter can be used for its normal purpose.
28 After a set time interval the dimensions of the
29 structure will be measured in the high load areas.
30 Because of the fact that high load areas have been
31 defined, the amount of measurements can be limited.
32 That means that the actual measurement of the

1 dimensions of the structure in the high load areas
2 involves relatively limited effort.
3 Using the measured dimensions of the structure it is
4 then possible to update the computer model and to
5 re-analyse the structure. This calculation will
6 result in an updated value for the integrity of the
7 structure. This means that the method according to
8 the present invention presents an efficient and
9 effective method for assessing the integrity of a
10 structure.

11

12 According to the present invention the method may
13 further comprise the step of:

14

15 viii) repeating one or more times steps v), vi) and
16 vii).

17

18 According to the present invention it is possible to
19 continuously measure the dimensions of the structure
20 in high load areas. Steps v), vi) and vii) can be
21 repeated after a set time interval, which time
22 interval may be dependent on the calculated value
23 for the integrity of the structure in a former
24 analysis.

25

26 According to the present invention the method may
27 comprise the further step of:

28

29 ix) visualising the results of vii).

30

31 The method according to the present invention is
32 suitable for continuously assessing the integrity of

1 a structure. In order to facilitate the review of
2 the outcome of the assessment, the results of the
3 calculations leading to the value for the integrity
4 of the structure can be presented, for instance, in
5 a table. This table can be presented to a plant
6 manager who thereafter can take necessary actions,
7 if needed.

8
9 According to the present invention the method may
10 comprise the further steps of:

11

12 x) measuring the actual load on the structure,

13

14 xi) updating the data relating to the load on the
15 structure, and thereafter

16

17 xii) re-analysing the structure, using the computer
18 model and the updated load data, in order to
19 calculate a value for the integrity of the
20 structure.

21

22 The method according to the present invention cannot
23 only be used for assessing the actual dimensions of
24 the structure, the method is also suitable for
25 measuring the actual load on the structure and using
26 the results of those measurements in order to refine
27 the calculations of the value for the integrity for
28 the structure.

29

30 According to the present invention the method may
31 comprise the further step of xiii) repeating one or
32 more times steps x), xi) and xii).

1 Moreover, the method may comprise the further step
2 of:

3
4 xiv) visualising the steps of step xii).

5
6 According to the present invention it is
7 advantageous that the method comprises the steps of
8 installing, after step iv), in high stress areas, a
9 first set of sensors for measuring the dimensions of
10 the structure in said high stress areas.. Moreover,
11 it is advantageous that the method comprises the
12 step of installing, after step iv), in high stress
13 areas, a second set of sensors for measuring the
14 load on the structure in said high stress areas.

15
16 The advantage of these measures is the fact that the
17 data relating to the dimensions of the structure and
18 the actual load on the structure can be collected
19 automatically. In order to process the collected
20 data in real-time it is an advantage that the method
21 comprises the step of connecting the sensors to
22 processing means, such as a computer, for
23 transmitting data from the sensors to the processing
24 means in real-time.

25
26 The method according to the present invention can be
27 used for new systems. The method, however, is also
28 suitable for structures which already have been used
29 during a certain time frame. In those cases it is
30 advantageous that the method comprises the step of
31 prior to step iv), collecting data relating to known
32 defects of the structure and thereafter using said

1 defect-data, the computer model of the structure and
2 the load-data for defining areas which are subject
3 to relatively high loads.

4

5 By adding the data relating to known defects of the
6 structure the calculation of high load areas in the
7 structure can be refined. Deterioration and growth
8 of the defects can then be measured and analysed.

9

10 In case there are no known defects, it is possible
11 that the method comprises the step of prior to step
12 iv), estimating the minimum size of defect in the
13 structure and thereafter using said estimated
14 defect-data, the computer model of the structure and
15 the load-data for defining areas which are subject
16 to relatively high loads. Moreover, it is possible
17 that the minimum size of the defect is estimated to
18 be equal to the precision the measurement equipment,
19 used for measuring the dimensions of the structure.

20

21 When the structure, to be analysed, is used for a
22 certain time period, and the load history on the
23 structure is known, it is possible that the method
24 comprises the step of prior to step iv), collecting
25 data relating to the load-history on the structure
26 and thereafter using said load-history, the computer
27 model of the structure and the load-data for
28 defining areas which are subject to relatively high
29 loads. Using this extra step of collecting data
30 relating to the load-history means that initial
31 calculations of high-load areas can be refined.

32

1 The invention also relates to a processing
2 arrangement for assessing the integrity of a
3 structure, provided with processing means, such as a
4 computer, for using data relating to the dimensions
5 of the structure and the load on the structure in a
6 calculation of a value representing the integrity of
7 the structure, wherein the processing arrangement is
8 provided with sensors to measure data relating to
9 the dimensions of the structure and the load on the
10 structure, the sensors being adapted to transmit
11 said data in real-time, wherein the processing means
12 are provided with receiving means for receiving said
13 data and wherein the processing means are adapted to
14 analyse the data in order to update the calculation
15 of the value representing the integrity of the
16 structure.

17

18 Preferably the processing arrangement is provided
19 with representation means for visualising the
20 results of the calculation of the value for the
21 integrity of the structure.

22

23 According to the invention it is possible that the
24 sensors used in the processing arrangement are
25 adapted to measure pressure exerted on the
26 structure, environmental loads, temperature,
27 mechanical loading on the structure, fluid loading
28 on the structure, vibration or acceleration
29 experienced by the structure.

30

1 The invention also relates to a structure, such as a
2 plant, provided with a processing arrangement as
3 described above.

4

5 The method according to the present invention can be
6 entirely controlled by a suitable computer program
7 after being loaded by the processing arrangement.
8 Therefore, the invention also relates to a computer
9 program product comprising data and instructions
10 that after being loaded by a processing arrangement
11 provides said arrangement with the capacity to carry
12 out a method as defined above.

13

14 Also a data carrier provided with such a computer
15 program is claimed.

16

17 Below, the invention will be explained in detail
18 with reference being made to the drawings. The
19 drawings are only intended to illustrate the
20 invention and not to limit its scope which is only
21 defined by the dependent claims.

22

23 Fig 1 shows a schematic overview of a processing
24 arrangement for assessing the integrity of a vessel.
25 Fig 2 shows a visual representation of the
26 calculations of a value for the integrity of a
27 structure.

28

29 Fig 3 shows a schematic overview of the software
30 used according to the present invention.

31

1 Fig 4 shows a diagram indicating the relation
2 between inspection costs, the number of inspections
3 and the corresponding risk.

4
5 In Fig 1 a schematic overview is shown of a
6 processing arrangement 10 for assessing the
7 integrity of a vessel. In order to assess the
8 integrity of the vessel 20, at an initial stage a
9 computer model will be created representing the
10 dimensions of the vessel 20. When creating said
11 computer model the presence of corroded areas 21 and
12 the presence of flaws, pits and cracks 22 can be
13 taken into account. The processing arrangement 10
14 comprises sensors 11 which are installed in high
15 load areas of the vessel 20. In Fig 1 only one
16 sensor is shown. In practice, several sensors will
17 be installed in order to allow a good overview of
18 the condition, strains and stresses in the vessel
19 20. The sensor 11 by means of a line 12 is
20 connected to a data logger 13. The data logger 13
21 is connected to processing means 14, such as a
22 computer. The computer 14 is provided with suitable
23 software in order to process the data generated by
24 the data logger 13. A possible architecture for the
25 software to be used in the computer 14 is described
26 with reference to Fig 3. By means of the sensor 11
27 the actual dimensions of the vessel 20 and the load
28 exerted on the vessel can be continuously measured
29 and can be forwarded to the computer 14. The
30 updated information sent to the computer 14 can be
31 used to constantly reanalysis the structure and

1 recalculate values for the integrity of the
2 structure.

3
4 The results of the calculations can be visualised,
5 for instance by means of a document centre 15. The
6 document centre 15 can be used, for instance, for
7 printing tables and overviews (see Fig 2), in order
8 to inform the responsible plant manager.

9
10 In Fig 1 reference numbers 23 and 24 are used for a
11 graphic representation of flaws, pits and cracks
12 which can be present in the vessel wall. During the
13 lifetime of the vessel the actual size of such
14 flaws, pits and cracks (in 3-d) will be used in
15 calculations of the value for the integrity of the
16 structure. That means that according to the present
17 invention no estimations of trends are used. The
18 actual sizes of the flaws, pits and cracks in the
19 system will be used when calculating the
20 representative value for the integrity of the
21 structure.

22
23 According to the present invention it is possible to
24 add a warning system. This warning system could
25 produce a warning when the value for the integrity
26 of the structure drops below a specific
27 predetermined level. It is also possible to
28 indicate on a visual representation the value for
29 the integrity of the structure has dropped below a
30 certain minimum.

31

1 In Fig 2 a possible outcome of the calculations are
2 shown. According to the requirements of a user, the
3 outcome of the calculations provides information on,
4 but not limited to, the working pressure inside the
5 vessel, the number of fatigue cycles to date, the
6 number of fatigue cycles remaining, current
7 corrosion rate, date until inspection is required,
8 the current safety factor, current risk factors,
9 etc. The visual representation of the outcome of
10 the calculations of the value for the integrity of
11 the structure can be tailored upon a user's request.
12 The visual representation according to Fig 2
13 provides a plant manager with a user-friendly
14 overview of the integrity of a structure.

15

16 In Fig 3 a schematic overview is given of a software
17 program which can be used in the method and
18 processing arrangement according to the present
19 invention. Because of the fact that the software
20 module provides an analysis system for plant real-
21 time integrity assessment, the software module could
22 be referred to as "Aspria". The software system is
23 built up from several modules. The overall system
24 will be referred to as "Integri-TECH".

25

26 The layout of the software system is shown in Fig 3.
27 The central part of the system is a so-called
28 management system or core system. The core system
29 manages and controls the components and will produce
30 the visual representation as shown in Fig 2. The
31 core system enables the different modules to work

1 together in order to produce a single outcome,
2 representing the integrity of a structure.

3
4 The core system comprises an analysis tool (Smart
5 FEA), which is a program based on finite element
6 analysis technology. This module includes advanced
7 error estimation techniques. The module contains
8 the "as-built" model of the structure to be
9 analysed, plus components and receives the regular
10 measurement data. When receiving the measurement
11 data this module will update the finite element
12 model and will perform an advanced finite element
13 analysis and thereafter passes the results to
14 further modules.

15
16 The core system also comprises a module for
17 assessment of a corrosion patch. This module can be
18 referred to as "envelope corrosion patch assessment"
19 (ECPA), which has been derived to assess the effects
20 of patches of corrosion in the various regions of
21 each structure to be analysed. The module generates
22 an envelope of possible conditions that will allow
23 the system to predict the earliest possible danger
24 signs for each structure. The corrosion patches can
25 be located and automatically updated every time a
26 corrosion measurement is taken or can be
27 automatically generated from measurement data,
28 adaptively meshed and can be dynamically positioned
29 anywhere on the structure to be analysed for
30 detailed finite element analysis. The results of
31 the analysis are modified to account for the most
32 likely severe and emerging patch shape and where the

1 results are becoming nearer to limiting values,
2 recommendations are passed back through the system
3 in order that the finite element analysis can modify
4 the finite element mesh in order to re-analysis the
5 system whereby the corrosion patches are included.

6
7 The core system further comprises a corrosion
8 trending analysis (CTA). This modules analyses the
9 history and trends and the future effects of
10 corrosion and erosion in the system. This module
11 moreover builds up on a history of the effects and
12 derives continually updating correlations to predict
13 corrosion rates, patterns, etc in order to be used
14 in a further statistical analysis module.

15
16 In case the structure to be analysed is in a high
17 temperature area, for instance in high energy piping
18 systems, a creep assessment system (CAS) can be
19 used. This module will analyse the temperature and
20 time history of a certain structure. Thereafter a
21 creep analysis of the system will be carried out to
22 simulate the stress changes due to time dependent
23 temperature effects in the piping system and will
24 build up a history of the effects and derive
25 continually updating correlations to predict creep
26 rates, patterns etc for the statistical analysis
27 module.

28
29 In case the structure to be analysed is subject to
30 acoustic pulsation, such as in gas compression
31 systems, a further harmonic-acoustic simulator (HIS)
32 can be used. This modules analyses the acoustic

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ART 34 AMET

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1 pulsations in the system by harmonic analysis to
2 simulate the stress changes due to acoustic
3 pulsations in the piping system. The history is
4 then stored and trends are predicted for the future
5 effects of acoustic pulsations in the system and the
6 system builds up a history of the effects and
7 derives continually updating correlations to predict
8 cyclic stress patterns. These cyclic stress patterns
9 can be used in a statistical analysis module.

10

11 In case the structure to be analysed is subject to
12 transient fluid flow conditions, such as in pumping
13 systems, the core system moreover uses a transient
14 simulator (TS). This module analyses the transient
15 fluid flow effects in the system by time history
16 analysis to simulate the stress changes due to
17 transient fluid flow effects in the piping system.
18 The history is then stored and trends predicted for
19 the future effects of transient fluid flow effects
20 in the system and the system builds up a history of
21 the effects and derives continually updating
22 correlations to predict cyclic stress patterns.
23 These cyclic stress patterns can be used in a
24 statistical analysis module.

25

26 The core system moreover comprises a statistical
27 analysis module. This module takes all of the
28 piping system loading history, cyclic patterns,
29 operational data, corrosion and erosion and B-Tech
30 vibration data and trends. These data then are
31 statistically analysed to provide realistic and
32 meaningful loading for first time history data for

1 the defect and fracture module. The same
2 information can be used in a fatigue life prediction
3 module to predict the remaining lifetime of the
4 structure before shutdown or failure. Standard
5 statistical analysis is then employed in the system.

6
7 The core system moreover is provided with a module,
8 adapted to receive "live measurements", including
9 frequency data, measured live by accelerometers, at
10 small bore branch connections. This module is
11 referred to as "B-Tech. The B-Tech part of the
12 system then performs extensive mathematical
13 correlations, algorithms and techniques to predict
14 the effect of the vibration and more importantly to
15 predict the fatigue life for the analysed structure
16 automatically from the measured data. The module,
17 if needed, can alert the user and can prevent
18 failure. Another important part of this module is
19 that the module isn't only capable of predicting the
20 fatigue life from vibration, but will also predict
21 which vibration excitation will cause problems for
22 each particular arrangement and will indicate these
23 vibration excitation if that level of vibration is
24 detected.

25
26 Results of these calculations will then be passed to
27 a further defect and fracture and FLP modules.

28
29 The core system moreover is provided with a liquid
30 sloshing simulator. This module performs the
31 simulation and assessment of liquid sloshing that
32 can take place when a vessel is located on a moving

1 object, such as a ship. Such liquid sloshing is
2 very detrimental to the integrity of the vessel and
3 can be catastrophic. Therefore it is most important
4 to assess the exact effects of the sloshing on the
5 integrity of the vessel. The liquid sloshing
6 simulator is adapted to simulate sloshing and to
7 predict the interaction of the sloshing with the
8 pressure vessel or a ship wall. The response of
9 these loadings to the ship (or a vehicle) motion is
10 measured and the cyclic loading pattern is generated
11 and passed through the finite element analysis
12 system for dynamic stress analysis. This analysis
13 is followed by a defect and fatigue analysis in
14 order to verify the integrity of the structure.

15

16 The core system moreover comprises a defect and
17 fracture module. This module performs the fracture
18 mechanics assessment. The system is adapted to
19 monitor, analyse and assess the growth of any defect
20 in the structure. The system integrity is then
21 quantified in respect of limiting crack and flaw
22 sizes that will affect the integrity. The location,
23 size and type of any possible defect or arrangement
24 of cumulative defects can be assessed and also
25 postulated defect assessments can be carried out.
26 For instance, every well in a structure, is assessed
27 and every range of defects is assessed at every
28 weld.

29

30 A further module present in the core system is the
31 fatigue life prediction module (FLP). This system
32 performs the fatigue life predictions.

1 The core system manages the various modules which
2 are shown in Fig 3. The specific features of those
3 six modules will be described below.

4
5 Aspria (analysis system for plant real time
6 integrity assessment) is an analysis, monitoring and
7 assessment system that can be connected to any
8 pressurised plant or structural system than can
9 deteriorate by erosion, corrosion or general
10 time/operation exposure and/or vibration. This
11 module quantifies the system's integrity, assesses
12 the effects of all loadings, stresses, defects and
13 predicts inspection and repair intervals as well as
14 plant life and safety. This is all done "on-line",
15 "live" or as "continuous monitoring system".

16
17 The Aspria module constantly measures geometric
18 thickness values in piping systems effected by
19 corrosion, erosion, vibration, etc. A detailed
20 geometric update is performed and the unit, whether
21 a piece of plant, such as pipework, a structure or
22 similar, will undergo an automatic and complete
23 finite element stress analysis using for instance
24 Smart-FEA (see above) and advanced error estimation
25 techniques to determine the degree of accuracy.
26 Defects, cracks or corrosion patches will be
27 thoroughly analysed automatically and a system
28 fatigue life automatically calculated. This will
29 lead to prescribed inspection and repair intervals,
30 and a quantified plant life. All loadings,
31 including process, mechanical and environmental
32 loadings, will be included in the assessment. If

1 the structure is used on a ship, the loading will
2 include sea motion.

3

4 The second module which can be used in the software
5 is Vecor (vessel corrosion analysis system for plant
6 real time integrity assessment). Vecor is an
7 analysis, monitoring and assessment system that can
8 be connected to any pressure vessel, tank or storage
9 system which can deteriorate by erosion, corrosion
10 or general time/operation exposure and/or vibration.
11 The system includes FPSO and ship movements and the
12 liquid sloshing and fluid structural interaction
13 effect of vessels on ships. Moreover Vecor will
14 include acceleration effects. It quantifies the
15 system and integrity, assesses the effects of all
16 loadings, stresses defects etc and predicts
17 inspection and repair intervals as well as plant
18 life and safety. This is all done "on-line", "live"
19 or as a continuous monitoring system. The Vecor
20 system will constantly measure geometric thickness
21 values in pressure vessels, exchangers and tanks
22 affected by corrosion, erosion, vibration etc.
23 Another item that Vecor can measure is the motion of
24 a ship or a platform. A detailed geometric and
25 loading update will then be performed and the
26 structure will undergo an automatic and complete
27 finite element stress analysis using for instance
28 Smart-FEA (see above) and advanced error measurement
29 techniques in order to determine the degree of
30 accuracy. Liquid sloshing effect within the vessel
31 will be simulated and assessed if appropriate (that
32 means when a ship pitches, heaves and rolls).

1 Interaction effects of the liquid sloshing and the
2 vessel structure response will also be assessed.
3 Defects, cracks or corrosion patches will be
4 thoroughly analysed automatically and a system
5 fatigue life automatically produced. This will lead
6 to prescribed inspection and repair intervals, plus
7 quantified plant life. All loadings, including
8 process, mechanical and environmental loadings will
9 be included in the assessments, including (if
10 appropriate) sea motion.

11 A further module to be used in the system is HEP-
12 TECH (high energy piping technology). HEP-TECH is
13 an analysis monitoring and assessment system which
14 can be connected to high energy or high temperature
15 piping systems in power stations or other markets,
16 where deterioration by creep, support load
17 variation, load and stress redistribution, high
18 temperature effects or general time/operation
19 exposure and/or vibration occurs. It quantifies the
20 system integrity, assesses the effects of all
21 support behaviour, loadings, stresses, defects and
22 predicts inspection and repair intervals as well as
23 plant life and safety. This is all done "on-line",
24 "live" or as "continuous monitoring system. The
25 HEP-TECH will constantly measure support load values
26 effected by deterioration and load redistribution
27 due to high temperatures of creep. A detailed load
28 update will then be performed and the pipework will
29 then undergo an automatic and complete finite
30 element stress analysis and advanced error
31 estimation techniques to determine the degree of
32 accuracy. The system will be assessed and the load

1 corrections required highlighted for adjustments,
2 which should be made to ensure piping and structural
3 integrity. Defects, cracks or potential areas for
4 such will be thoroughly analysed automatically and
5 the system fatigue life will be produced
6 automatically. This will lead to a prescribed
7 inspection and repair intervals, plus quantified
8 plant life. The assessments will include all
9 loadings such as process, mechanical and
10 environmental loadings. The potential for "leak
11 before break" will also be assessed.

12 ..
13 A further module is the AP-Tech (acoustic pulsation
14 technology). AP-Tech is an analysis, monitoring and
15 assessment system to monitor, predict, simulate and
16 assess the effects and levels of acoustic energy
17 waves and frequencies in process plant piping
18 systems. It also assesses the levels of dynamic
19 excitation and vibration of the piping system but
20 also has a module to prevent and identify a solution
21 to the majority of small bore bench connection
22 stress, vibration and fatigue problems. AP-Tech
23 quantifies the piping system integrity, assesses the
24 effects of all pulsation and piping behaviour,
25 dynamic and fluid loadings, stresses, defects and
26 small bore branches and predicts inspection and
27 repair intervals as well as plant life and safety.
28 These are all done "on-line", "live" or as a
29 "continous monitoring system". The AP-Tech system
30 would constantly measure life acoustic pulsation
31 pressure waves and the associated frequency and
32 vibration values effected by acoustic pulsation and

1 vibration, etc. The detailed dynamic loading update
2 will then be performed and the pipework will undergo
3 an automatic and complete dynamic finite element
4 stress analysis. Moreover, error estimation
5 techniques will be used in order to determine the
6 degree of accuracy. AP-Tech will use either a
7 pressure transducer or a non-intrusive method to
8 measure acoustic pulsations. The system will be
9 dynamically assessed, the acoustic pulsation
10 simulated and the acoustic-dynamic-vibration load
11 cycle pattern and subsequent fatigue life will be
12 determined. A computational fluid dynamic simulator
13 will optionally be attached to allow a user to
14 "visualise" the acoustic pulsation behaviour of the
15 system. All necessary timescales and indications of
16 work areas required will be produced "automatically
17 which should be made to ensure piping and structural
18 integrity. Defects, cracks or potential for such
19 will be thoroughly analysed automatically and the
20 system fatigue life will be produced automatically,
21 which will lead to prescribed inspection and repair
22 intervals, plus a quantified plant life. All
23 loadings, including process, mechanical, pulsation,
24 acoustic, vibration and environmental loadings will
25 be included in the assessment.

26
27 A further module to be used in the system is F-Tech.
28 This is a module which provides beneficial analysis
29 and monitoring and assessment for the majority of
30 piping and vessel-tank flange connections. The
31 problems to monitor involve stress, vibration,
32 leakage and fatigue. F-Tech quantifies the flange

1 joint integrity, assesses the effects of all flange
2 loadings, gaskets, bolts, stresses and predicts
3 inspection and repair intervals as well as plant
4 life and safety. This is all done "on-line", "live"
5 or as "continuous monitoring" system. F-Tech will
6 provide a detailed geometric update of the monitored
7 area and then the area will undergo an automatic and
8 complete finite element stress analysis and advanced
9 error estimation techniques to determine the degree
10 of accuracy. Flange displacement and rotation will
11 be assessed along with gasket seating pressure in a
12 live and automatic mode. This will be thoroughly
13 analysed "automatically" and the system fatigue
14 life, joint relaxation plus potential for joint
15 leverage will be automatically produced. This will
16 lead to prescribed inspection and repair intervals,
17 plus quantified plant life. All loadings including
18 process, mechanical and environmental loadings will
19 be included in the assessment.

20

21 A further module to be used is called Trans-Tech.
22 This module is adapted to monitor, predict, simulate
23 and assess the effects of the majority of piping
24 transient events such as fluid transient and energy
25 waves and frequencies in process plants piping
26 systems. It also assesses the levels of dynamic
27 excitation and vibration of the piping system.
28 Moreover, Trans-Tech has a module to prevent and
29 identify a solution to the majority of small bore
30 branch connections stress, vibration and fatigue
31 problems. Trans-Tech quantifies the piping system
32 integrity, assesses the effects of all fluid

1 transient and piping behaviour, dynamic and fluid
2 loadings, stresses, defects, small bore branches and
3 thereafter predicts inspection and repair intervals
4 as well as plant life and safety. This is all done
5 "on-line", "live" or as a "continuous monitoring"
6 system. A computation fluid dynamic simulator will
7 optionally be attached to allow clients to visualise
8 the acoustic pulsation behaviour of the system. All
9 necessary timescales and indications of work areas
10 required will be produced automatically which should
11 be made to ensure piping and structural integrity.

12
13 All six modules, described above, have the option of
14 utilising accelerometers to include the effects of
15 system vibration. All systems have preset intervals
16 for the automatic measurement readings and
17 subsequent re-analysis. This is determined by the
18 user and could be adapted in order to analyse and
19 measure every hour all day, or any other time
20 interval. The cost of the modular architectural
21 software the Integri-Tech system can be set up for
22 any structure, any piece of plant, pressure vessels,
23 equipment, civil buildings, structures, ships and
24 buried pipes.

25
26 In order to collect the data to be processed by the
27 software as described above the processing
28 arrangement according to the present invention uses
29 measurement hardware components which will include:

30
31 Ultrasonic thickness, ultrasonic blanket thickness
32 measuring devices, accelerometers, data transmittal

1 devices, data interface devices, acoustic
2 measurement systems, pressure transducers, non-
3 intrusive PVDF systems, pipe support load
4 measurement cells, strain gauges, ground settlement
5 gauges, gyroscopes and ship-vehicle motion devices,
6 acoustic emission systems, patch corrosion
7 measurement devices, radiography interfaces, MAP
8 scan interfaces, intelligent pigging interfaces, and
9 crack growth measurement devices.

10

11 The advantages of using the system according to the
12 present invention include:

13

14 The generation of information to protect inspection
15 and remedial action plans. Since all necessary
16 information on the critical areas of a structure are
17 known, the use of the system will lead to a
18 reduction of risks and a reduction of inspection
19 costs. Moreover, the system provides real time
20 information on the integrity of the system, which
21 enables prompt action if required.

22

23 In Fig 4 the possible advantages of the system
24 according to the present invention are shown. Line
25 X represents the amount of costs involved with a
26 respective number of inspections. Line Y represents
27 the relation between possible risks and the number
28 of inspections. Line Z represents a modified
29 relation between risks involved and the number of
30 inspections when using the system according to the
31 present invention.

32

1 Fig 4 shows that using the system according to the
2 present invention will lead to a lower level of
3 risk, while at the same time the number of
4 inspections (meaning the costs involved as
5 inspections) will decrease.

1 CLAIMS

2

3 1. Method for assessing the integrity of a
4 structure, comprising the steps of:

5

- 6 i) collecting data relating to the initial
7 dimensions of the structure,
8 ii) creating a computer model of the structure,
9 iii) collecting data relating to the estimated load
10 on the structure,
11 iv) analysing the structure, using the computer
12 model of the structure and the load data, in
13 order to define areas which are subject to
14 relatively high stresses,
15 v) measuring, after a time interval, the
16 dimensions of the structure in high stress
17 areas,
18 vi) updating the computer model of the structure,
19 using the results of step v),
20 vii) re-analysing the structure, using the updated
21 computer model and the load data, in order to
22 calculate a value for the integrity of the
23 structure.

24

25 2. Method according to Claim 1, wherein the method
26 comprises the step of:

- 27 viii) repeating one or more times steps v), vi) and
28 vii).

29

30 3. Method according to Claim 1 or 2, wherein the
31 method comprises the step of:

- 32 ix) visualising the results of step vii).

1 4. Method according to Claim 1, 2 or 3, wherein the
2 method comprises the steps of:

- 3 x) measuring the actual load on the structure,
4 xi) updating the data relating to the load on the
5 structure, and thereafter
6 xii) re-analysing the structure, using the computer
7 model and the updated load data, in order to
8 calculate a value for the integrity of the
9 structure.

10

11 5. Method according to Claim 4, wherein the method
12 comprises the step of:

- 13 xiii) repeating one or more times steps x), xi) and
14 xii).

15

16 6. Method according to Claims 4 or 5, wherein the
17 method comprises the step of:

- 18 xiv) visualising the results of step xii).

19

20 7. Method according to one of the preceding claims,
21 wherein the method comprises the step of installing,
22 after step iv), in high stress areas, a first set of
23 sensors for measuring the dimensions of the
24 structure in said high stress areas.

25

26 8. Method according to one of the preceding claims,
27 wherein the method comprises the step of installing,
28 after step iv), in high stress areas, a second set
29 of sensors for measuring the load on the structure
30 in said high stress areas.

31

1 9. Method according to Claim 7 or 8, wherein the
2 method comprises the step of connecting the sensors
3 to a processing means, such as a computer, for
4 transmitting data from the sensors to the processing
5 means in real time.

6

7 10. Method according to one of the preceding claims,
8 wherein the method comprises the step of prior to
9 step iv), collecting data relating to known defects
10 of the structure and thereafter using said defect-
11 data, the computer model of the structure and the
12 load-data for defining areas which are subject to
13 relatively high loads.

14

15 11. Method according to one of the preceding claims,
16 wherein the method comprises the step of prior to
17 step iv), estimating the minimum size of defects in
18 the structure and thereafter using said estimated
19 defect-data, the computer model of the structure and
20 the load-data for defining areas which are subject
21 to relatively high loads.

22

23 12. Method according to Claim 11, wherein the
24 minimum size of the defects is estimated to be equal
25 to the precision of the measurement equipment, used
26 for measuring the dimensions of the structure.

27

28 13. Method according to one of the preceding claims,
29 wherein the method comprises the step of prior to
30 step iv), collecting data relating to the load-
31 history on the structure and thereafter using, said
32 load-history, the computer model of the structure

1 and the load-data for defining areas which are
2 subject to relatively high loads.

3

4 14. Processing arrangement for assessing the
5 integrity of a structure, provided with processing
6 means, such as a computer, for using data relating
7 to the dimensions of the structure and the load on
8 the structure in a calculation of a value
9 representing the integrity of the structure, wherein
10 the processing arrangement is provided with sensors
11 to measure data relating to the dimensions of the
12 structure and the load on the structure, the sensors
13 being adapted to transmit said data in real-time,
14 wherein the processing means are provided with
15 receiving means for receiving said data and wherein
16 the processing means are adapted to analyse the data
17 in order to update the calculation of the value
18 representing the integrity of the structure.

19

20 15. Processing arrangement according to Claim 14,
21 wherein the processing arrangement is provided with
22 representation means for visualising the result of
23 the calculation of the value representing the
24 integrity of the structure.

25

26 16. Processing arrangement according to Claim 14 or
27 15, wherein the sensors are adapted to measure
28 pressure exerted on the structure.

29

30 17. Processing arrangement according to Claim 14 or ..
31 15, wherein the sensors are adapted to measure
32 temperature.

1 18. Processing arrangement according to Claim 14 or
2 15, wherein the sensors are adapted to measure
3 mechanical loading on the structure.

4

5 19. Processing arrangement according to Claim 14 or
6 15, wherein the sensors are adapted to measure fluid
7 loading on the structure.

8

9 20. Processing arrangement according to Claim 14 or
10 15, wherein the sensors are adapted to measure
11 vibration.

12 ..

13 21. Processing arrangement according to Claim 14 or
14 15, wherein the sensors are adapted to measure
15 acceleration experienced by the structure.

16

17 22. Structure, such as a plant, provided with a
18 processing arrangement according to Claims 14-21.

19

20 23. A computer program product comprising data and
21 instructions that after being loaded by a processing
22 arrangement provides said arrangement with the
23 capacity to carry out a method according to Claims
24 1-13.

25

26 24. A data carrier provided with a computer program
27 product according to Claim 23.